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Watertown Arsenal
Report No. 612/27
(Ex.O. 44-A-1)

January 6, 1942

BEHAVIOR OF ALLOY AND DEOXIDIZER ADDITIONS IN GUN STEEL

OBJECT

To study the behavior of alternative sources of alloys and deoxidizers for Watertown Arsenal gun composition.

SCOPE

This report deals with possible substitutes for the alloys and deoxidizers used in present melting practice to make Watertown Arsenal gun composition, namely,

C	.20-.25%	Si	.15-.35%
Mn	.60-.90%	Cr	1.00-1.10%
P	.025% Max.	Mo	.45-.55%
S	.025% Max.	V	.08-.12%

No attempt is made to evaluate the present or future availability of any of these ferro-alloys.

CONCLUSIONS

1. The advantages gained through use of a few of the alternate or substitute materials studied are minor. In many cases disadvantages arise. It is believed that the present practice should be continued until conditions affecting the arsenal are changed.

2. Should changes become necessary, the following substitutions could be made with no change in melting technique and no difficulty:

[redacted]

Material	Substituted for
Carbon	Pig Iron
80% Ferro-manganese	96% Ferro-manganese
Electrolytic Manganese	96% Ferro-manganese
Silico-manganese	96% Ferro-manganese
95% Ferro-silicon	50% Ferro-silicon
High Silicon Silico-manganese	50% Ferro-silicon
Chromium metal	70% Ferro-chromium
Grainal	40% Ferro-vanadium

3. The following substitutions could be made only with great difficulty or with a radical change in practice:

Material	Substituted for
Speigeleisen	Pig Iron and part of 96% Ferro-manganese
Calcium Molybdate	60% Ferro-molybdenum
Chrom-X	70% Ferro-chromium

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INTRODUCTION

To study the behavior of alternative sources of alloys and deoxidizers for Watertown Arsenal gun composition a series of some thirty heats was made of that analysis. In each of these heats one ferro-alloy was substituted directly for another with no other change in practice; for example, eletrolytic manganese was substituted for the present 96% ferro-manganese, or 95% ferro-silicon was substituted for the present 50% ferro-silicon, etc. All heats were made in duplicate. Furnace practice on all heats was identical except for the substitution. The heats, 60 lb. in size, were cast in the Model (T-3) centrifugal casting machine.

Chemical analysis and "as cast" macro-etch tests were taken from the castings. Since the analysis made in each heat was Watertown Arsenal gun composition it was thought unnecessary except in one or two cases to heat treat the castings and determine their physical properties.

DATA AND DISCUSSION

Material Studied

The following substitutions were studied:

1. For Pig Iron

   a. Carbon in the form of small electrodes was added at high temperature.

2. For 96% Ferro-manganese

   a. 80% Ferro-manganese, a high carbon electric furnace product.

b. Electrolytic Manganese, a product refined by wet electrolytic methods from low grade manganese ores.

c. Silico-manganese, a high carbon high silicon electric furnace product.

d. Speigeleisen, a high carbon, high manganese iron.

3. For 50% Ferro-silicon

a. 95% Ferro-silicon, a purer grade of electric furnace ferro-silicon.

b. High Silicon Silico-manganese, a high manganese electric furnace silicon.

4. For 70% Ferro-chromium

a. Chromium metal.

b. Low carbon Chrom-X, an exothermic mixture of chromium ore.

c. High Nitrogen Ferro-chromium, an electric furnace Ferro-chromium high in nitrogen.

5. For 60% Ferro-molybdenum

a. Calcium molybdate, a compound containing about 35% molybdenum and 15% calcium, in duplex oxide form.

6. For 40% Ferro-vanadium

a. Grainal #1, a vanadium-titanium-aluminum electric furnace ferro-alloy.

Table No. I gives typical analyses of these materials used.

Melting Behavior and Alloy Recovery

The difficulties encountered in making these heats are worth noting. A thin watery low temperature slag was formed in excessive amounts when Chrom-X or Calcium molybdate was used. It was impossible to completely remove this slag before pouring and a considerable quantity of it was carried into the pouring box. Chrom-X gave very low chromium recovery. When Speigeleisen was used excessive slag was formed and the large addition (necessary because of its analysis) chilled the metal bath sufficiently to delay the heat considerably. Speigeleisen gave very low manganese recovery.

Table No. II lists the over-all efficiencies for the various elements when either standard or substitute materials were used.

Macro-etch examination of "as cast" discs showed all castings to be acceptable and of quality equal to standard castings except those made using High Nitrogen Ferro-chromium. Although the macro-etches were very poor on castings made with high nitrogen ferro-chromium, the physical properties when heat treated were satisfactory.

Table No. III gives the physical properties of the castings that were heat treated with the usual normalize (2200°F for 16 hrs.), quench (from 1650°F), and draw (temperature varies with analysis). Figure 1 shows the location of these test specimens.

TABLE NO. I

Typical Analyses

	C	Mn	Si	Cr	Mo	V	Fe
Watertown Arsenal Ferro-Alloys							
Pig Iron	4.40	0.17	0.85				94.5
96% Ferro-manganese	0.15	96.30	0.82				3.6
50% Ferro-Silicon			49.82				50.0
70% Ferro-chromium	0.08	0.23	0.26	69.42			29.0
60% Ferro-molybdenum	1.40	0.09	0.42		65.41		32.5
40% Ferro-vanadium	0.34	0.40	1.12			38.35	59.5
Substitute Ferro-Alloys							
Carbon electrode	99.7						
80% Ferro-manganese	3.60	80.04					16.0
Electrolytic Manganese		99.9					
Silico-manganese	5.08	20.20	1.17				73.0
Speigeleisen	2.06	68.13	14.70				15.0
Silico-manganese	0.56	67.93	21.35				10.0
95% Ferro-silicon			93.87				6.0
Chromium metal	0.15		0.48	97.76			0.7
Chrom-X	0.20			25.0			15.0
* High Nitrogen Ferro-chromium	0.56			68.72			29.0
** Calcium Molybdate					35.70		
x Grainal #1			3.97	0.11		24.89	44.0

* 0.72% Nitrogen
** 14.8% Calcium
x 17.24% Titanium, 9.03% Aluminum

TABLE NO. II

Over-all Recovery Efficiencies of Additions

$$\left(\frac{\text{Amount in finished casting}}{\text{Amount charged}} \times 100 \right)$$

	C %	Mn %	Si %	Cr %	Mo %	V %	Al %	Ti %
Standard (Average	90	64	56	93	90	92	-	-
Carbon electrode	93							
80% Ferro-manganese		60						
Electrolytic Manganese		62						
Silico-manganese		61	71					
Speigeleisen	85	40						
High Silicon Silico-manganese		68	69					
95% Ferro-silicon			55					
Chromium metal				96				
Chrom-X				61				
High Nitrogen Ferro-chromium				100				
Calcium Molybdate					97			
Grainal #1						91	39	73

TABLE NO. III

Physical Properties After Heat Treatment

2200°F - 16 hrs. - Air Cool
1650°F - 6 hrs. - Water Quench
Drawn 6 hrs. as shown below

Casting No.	Draw Temp. °F	Made With	Test Location	Y. S. * p.s.i.	T. S. p.s.i.	Elong. %	R.A. %	Charpy Tensile	Brinell Hardness
(37 m/m Required				95./120,000	-	-	40.0		
(37 m/m Average Properties				112,000	140,000	18.0	58.0	-	293
265	1200	High Nitrogen	6-T	108,000	143,800	16.4	52.9	26.8	321
		Ferro-Chromium	12-T	109,000	146,000	17.1	52.5	30.1	
		" "	12-L	105,500	143,200	17.1	54.8	10.6	
266	1200	" "	6-T	116,000	144,000	18.0	57.8	49.9	-
		" "	12-T	115,000	144,200	18.6	54.8	52.0	
		" "	12-L	114,000	140,400	15.7	51.0	41.0	
267	1200	Grainal	6-T	115,500	151,800	15.0	46.1	36.1	351 - 321
		"	12-T	115,500	151,200	15.7	47.4	31.0	
		"	12-L	112,000	145,400	16.4	54.8	28.0	
268	1200	"	6-T	119,000	157,200	14.3	45.7	43.7	351 - 340
		"	12-T	118,000	156,600	14.3	47.0	43.5	
		"	12-L	118,000	155,000	15.0	48.6	44.2	
374	1185	Chrom-X	6-T	-	142,000	18.0	54.4	64.1	321 - 286
		"	12-T	110,000	141,500	18.0	54.1	55.5	
		"	12-L	107,500	141,000	18.0	55.2	61.3	
375	1185	"	6-T	-	132,000	19.3	57.8	12.7	302 - 293
		"	12-T	100,500	133,500	18.6	56.3	7.5	
		"	12-L	98,000	132,000	17.1	55.9	20.1	

* Yield Point by the 0.01% offset method.

FIGURE 1.

Machining of Model Centrifugal Castings For Testing.

Machining of Model Centrifugal Castings for Testing

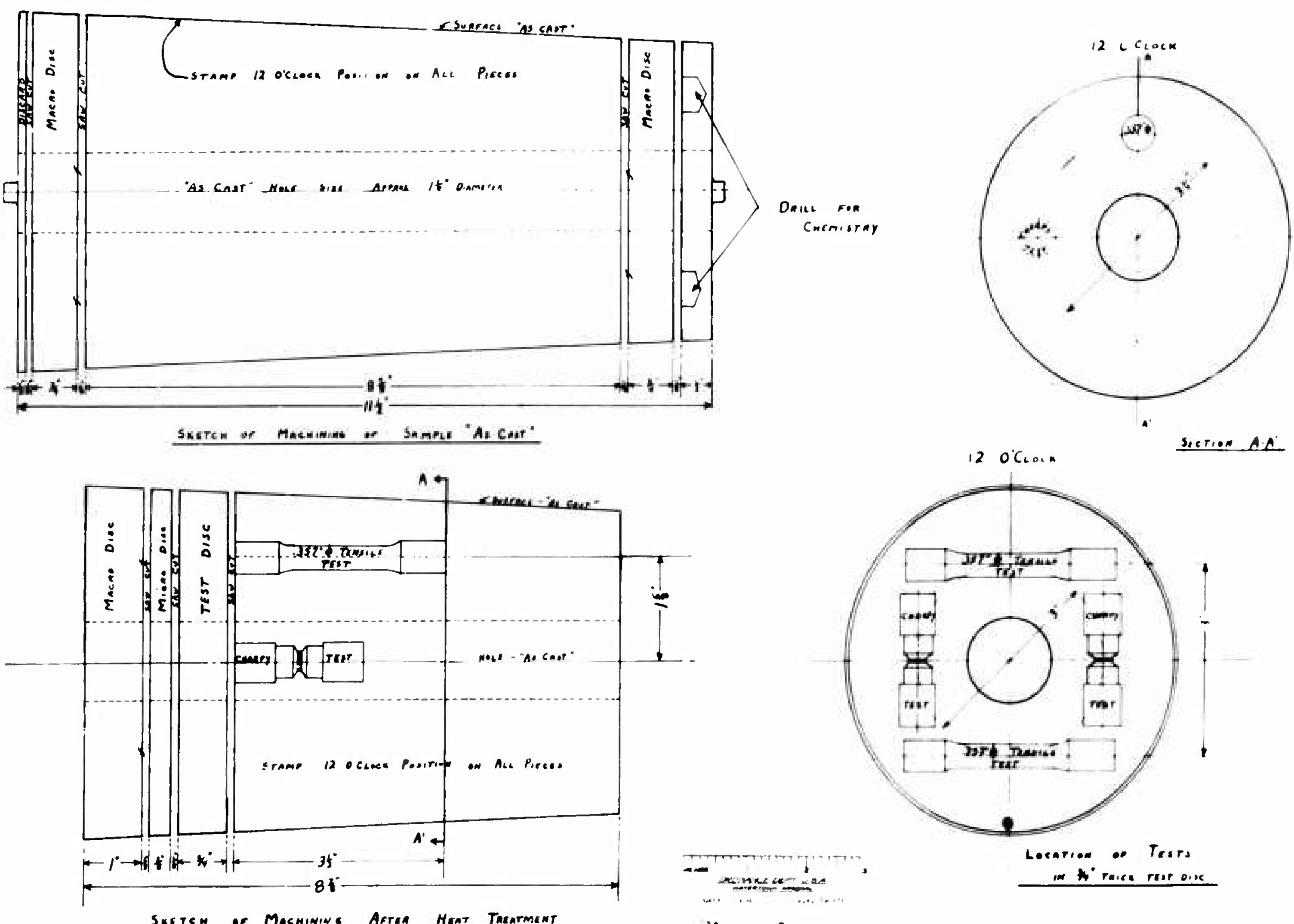

Figure 1.